

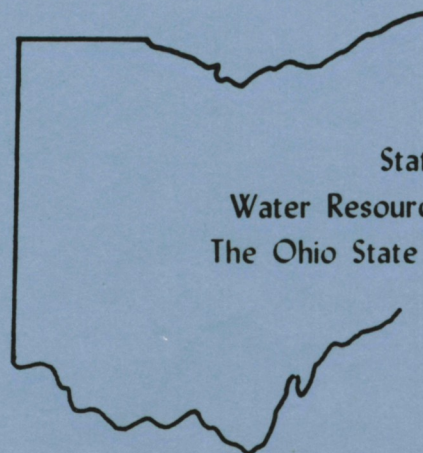
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Report No. G-1442-01

**FISCAL YEAR 1987
PROGRAM REPORT**

Robert C. Stiefel
Director

United States
Geological Survey



State of Ohio
Water Resources Center
The Ohio State University

Report No.
G-1442-01

Fiscal Year 1987 Program Report
Grant No. 14-08-0001-G1442

for

U. S. Department of the Interior
Geological Survey

by

Water Resources Center
The Ohio State University
Columbus, Ohio 43210

Robert C. Stiefel, Director

August, 1988

The activities on which this report is based were financed in part by the Department of the Interior, U. S. Geological Survey, through the Ohio Water Resources Center.

The contents of the publication do not necessarily reflect the views and policies of the Department of the Interior, nor does mention of trade names or commercial products constitute their endorsement by the United States Government.

ABSTRACT

Water is one of Ohio's most important natural resources, and the State has an adequate supply to meet its immediate needs. Most of Ohio's water problems are associated with water quality. Of primary concern are the sediments, nutrients, and acids in the surface waters from urban, agricultural and mining areas, and the toxic and hazardous waters that threaten the ground and surface waters. The focus of the 1987 State Water Research Program was directed at some of these needs. One project explored the design criteria for an innovative two-stage fluidized bed bioreactor in which the three major process of cell immobilization, biodegradation, and biofilm control were combined in a single unit. This wastewater treatment process is felt to be a substantial evolution in the operational technology of bioreactor design and the successful completion of this project could result in the development of an innovative, reliable and considerably less costly wastewater treatment system. Another project's research was a cooperative effort with OEPA, ODNR, and the Nature Conservancy in examining and assessing the potential institutional and legal constraints that might hinder the development of programs for the management of non-point sources of pollution. Two projects explored the fate and transport of agricultural chemicals as they moved through soils toward the groundwater table. One studied the effects that subsurface agricultural drains have on the movement of pesticides to groundwaters. The other explored the potential impacts that interactions and reactions between herbicides and existing humic materials have on the fate and transport of the herbicides in the groundwater. Training was provided for ten students enrolled in five disciplines in at three universities in Ohio.

TABLE OF CONTENTS

	Page
Abstract	i
Water Problems and Issues of Ohio	1
Program Goals and Priorities	6
Research Project Synopses:	
• Optimal Design of Fluidized Bed Bioreactors for Wastewater Treatment - L. S. Fan	11
• Application of Gaming and Decision Analysis to the Assessment of Legal/Institutional Arrangements for Nonpoint Pollution Control - S. I. Gordon	14
• A Study of Potential Groundwater Contamination from Selected Agricultural Pesticides - L. C. Ruedisili.	17
• Effect of Complexation by Soluble Humic Substances on the Aqueous Transport and Chemistry of Pesticides.	21
Information Transfer Activities	24
Cooperative Arrangements	27
Training Accomplishments	31

WATER PROBLEMS AND ISSUES OF OHIO

Water is one of Ohio's most important natural resources. Bounded on the north by Lake Erie and on the south by the Ohio River and containing other extensive ground and surface waters, Ohio has an adequate supply of water to meet its immediate needs. However, the combination of large, heavily industrialized urban centers; extensive agricultural activities; high volume coal production and large coal reserves; and the associated demands for new energy production continues to cause concerns related to water quality and water management. In addition, extreme hydrologic events cause localized problems of both excessive water and water deficiencies at times.

Surface Water

The northern twenty-five percent of Ohio's area drains into Lake Erie, while the southern portion drains into the Ohio River. Runoff from Ohio's streams and rivers averages about 25 billion gallons per day. The state also receives nearly a billion gallons of runoff daily which drains through the Maumee River to Lake Erie from the neighboring state of Indiana; and Ohio has access to additional flows past its boundaries in Lake Erie and the Ohio River that total well over 150 billion gallons of water per day.

Last year, over 16 billion gallons of water were withdrawn from Ohio's surface sources each day to meet the demands for municipal supplies; rural needs for domestic and livestock purposes; irrigation; and self-supplied industrial needs including cooling water for thermoelectric power generation. These demands account for only 60 percent of the available surface waters in the state's streams each day, and localized shortages only develop during certain dry seasons and periodic droughts.

The combined length of all the streams in Ohio approaches 44,000 miles, which means that there is approximately one mile of stream for each square mile of surface area in the state. In addition, there are more than 50,000 lakes, ponds and reservoirs within the state having a combined surface area of 200,000 acres. Only a small fraction of these, about 6,700 acres, occur naturally. The remainder are man-made impoundments that range in size from small farm ponds to large multipurpose reservoirs.

The reservoirs in the state are used to provide water for many different purposes including municipal, agricultural and industrial supplies; stream flow augmentation; flood control; and recreation. No impoundments in Ohio, other than those on the main stem of the Ohio River, provide water for downstream navigation or hydro-electric power generation. However, there is extensive navigation on both Lake Erie and the Ohio River, and consideration is being given to the installation of low-head hydro-electric generators at several developed dam sites throughout the state.

Flooding, still a major problem in Ohio, affects both urban and agricultural areas; and it has been estimated that nearly two million acres of land in Ohio are flood prone. This represents over seven percent of the total area of the state and includes nearly four percent of those areas classified as urban regions. Average annual flood damages in Ohio vary from year-to-year but amount to several millions of dollars annually.

Ground Water

Ground water is an important part of Ohio's water resources. Ground water underlies most of the state but is predominant in the glacial drift in the northwest, in the ice-contact and outwash deposits in river valleys along the border of the glaciated areas, and in the bedrock of the western portions of the state. Ground water supplies are largest in the glacial valley-train deposits in those drainage basins which border the Ohio River including the Ohio, Miami, Little Miami, Scioto, Hocking and Muskingum Rivers. Well yields from these deposits often exceed 500 gallons per minute (gpm), while aquifers in the glacial drift in the northwest and west-central parts of the state produce yields between 100 and 500 gpm. Isolated aquifers in the northeast, northwest and southwest have yields between 25 and 200 gpm, while much of the northeast contains aquifers whose yield is between 5 and 25 gpm. With the exception of the valleys along the major streams, most of the aquifers in the area that is tributary to the Ohio River have yields less than 5 gpm.

Three-quarters of Ohio's 650 public water supply systems use ground water as their source. In terms of volume withdrawn, however, a lesser share of these supplies comes from ground water, for only around a half billion gallons of ground water are withdrawn each day for public water supply purposes, while over one billion gallons come from surface water sources. However, ground water supplies nearly 80 percent of the rural water needs in Ohio, 32 percent of the irrigation waters and 21 percent of the industrial water demands. Nearly one billion gallons of ground water are withdrawn in the state each day to meet these needs.

Water Quality

It is the quality of water, rather than its quantity, that is the more critical and limiting condition associated with the use of both ground and surface waters in Ohio. The ground waters of the state frequently have relatively high, natural mineral contents; but, except for a few local areas, most of these waters are free from man-related contamination. Most complaints are related to increased levels of turbidity, bacterial populations and other substances from improperly sited or poorly constructed or maintained wells. Other problems are related to the spillage and leakage of brines and petroleum at oil wells in the southeastern part of the state; the mis-application of pesticides, herbicides and insecticides in agricultural areas; and the improper siting and operation of solid and liquid waste disposal facilities. Some minor ground water problems associated with the excessive use of highway de-icing salts or its improper storage have also been reported.

The dissolved solids concentrations in Ohio's streams range between 120 and 2,500 milligrams per liter (mg/l). The higher concentrations are found in the Tuscarawas, Cuyahoga and Grand Rivers and in other stream reaches below major municipal and industrial outfalls or in areas subjected to diffuse source runoff.

Of the 23,000 miles of the principal rivers downstream of major urban areas in the state that have been monitored, 16,000 miles, or 70 per cent of these streams, meet the current water quality standards. Where problems do exist, they are frequently caused by inadequate municipal wastewater treatment at facilities that need be upgraded or expanded, or by combined sewer overflows. Substantial improvements in surface water quality have resulted from the development of pretreatment regulations for industrial waste discharges to municipal sewerage systems. Violations of the state's water quality standards occur most often in dissolved oxygen levels; ammonia nitrogen concentrations; the numbers of fecal coliforms; and the levels of heavy metals such as lead, zinc, and cadmium.

Acid mine drainage is a major cause of water quality problems throughout the Appalachian Coal Basin in the eastern United States. In Ohio this region extends in a band approximately 50 miles wide in a southwesterly direction from the east-central to the south-central parts of the state. Acid drainage from abandoned and improperly operated or reclaimed coal mined lands causes a loss of water for domestic and industrial uses; the degradation of water quality for recreational purposes; a lethal impact on the aquatic life in a stream; and an accelerated deterioration of highway and railroad bridges and electrical transmission lines and towers. Drainage from abandoned coal mines, both surface and underground, has impacted around 1,500 miles of streams in 27 counties in southeastern Ohio. Approximately 370,000 acres of abandoned strip mines, 7,000 acres of coal refuse piles and 3,000 under-

ground mines are contributing to this problem. It has been estimated that four billion dollars would be needed to reclaim the abandoned mines and refuse piles throughout Ohio. Projected revenues from severance taxes earmarked for abandoned mine reclamation come to about ten million dollars annually. Obviously, the technologic problems and the economic costs associated with the control of acid mine drainage will continue to keep this a major problem of water quality in southeastern Ohio for years to come.

Little detailed information is available concerning the impacts that diffuse sources of pollution such as agricultural and urban stormwater drainage have on the quality of water in Ohio's inland streams. One concern with non-point pollution is the sediment that is dislodged from the land surface and carried to the streams. Of greater concern are the pollutants, such as the nutrients, heavy metals and toxic organic substances, that enter the streams attached to the sediments. No need for intensive, non-point source control programs to meet water quality standards in that area of the state that drains to the Ohio River has been shown; but several studies are underway in the Lake Erie drainage basin to define the role of agricultural drainage on the water quality in the lake. Much more research and many more demonstration projects on the best management practices for agriculture, silviculture, mining and urban runoff control must be conducted before this problem is fully understood and control measures can be instituted.

The trophic status of several lakes and reservoirs has been studied; and the results suggest that the lakes and reservoirs in the sandstone bedrock areas of the state have generally lower trophic levels than those in the limestone bedrock areas or glaciated regions. Water quality was generally good to excellent in most of the lakes and reservoirs surveyed. However, excessive concentrations of copper and other heavy metals, bacteria and other pollutants normally associated with urban activities were identified in some of the lakes.

Recent studies on Lake Erie indicate that there has been a reduction in several key pollutants and a gradual, but steady, improvement in the water quality in the Lake during the past few years. Phosphorus is a major pollutant which results in the excessive growth of algae and other aquatic plants. As these plants die and decay, they deplete the oxygen resources of the Lake. The construction of facilities to remove phosphorus at those municipal wastewater treatment plants which discharge directly to Lake Erie has been a major factor in the reduction of phosphorus loadings and of the subsequent reduction of the anoxic areas within the Lake. Additional work on the control of phosphorus from both diffuse sources and point sources needs be accomplished, but a significant start has been made.

Levels of bacteria have been reduced in the nearshore zones where municipal wastewater treatment facilities have been constructed. This has permitted regulatory agencies to re-open bathing beaches which were often closed during the period between 1960 and 1970. Concentrations of mercury and pesticides have been reduced substantially, principally because of the federal bans that have been instituted on their manufacture, use and disposal. PCB remains a major challenge, as does the control of sediment and the nutrients, fertilizers and organic chemicals that are attached to it.

Fish populations, including the walleye pike, are beginning to increase again in the lake; but the quality and diversity of fish is still far from what they were in the past. Thermal pollution is a localized problem in some near-shore areas. However, as closed cycle cooling is required on all power generation facilities, the extent of this problem will diminish.

PROGRAM GOALS AND PRIORITIES

The Water Resources Center at The Ohio State University encourages and supports research that is directed at providing information needed to solve the major water problems at the local, state, regional and national levels. The research program at the Center includes basic or fundamental research, problem oriented or applied research, and information dissemination and technology transfer activities.

During FY 1982, the Center, in cooperation with several groups of water-related agencies and officials throughout the State prepared a prioritized list of Ohio's major water resources problems. Based upon this analysis, the following ranking of these problems was developed:

1. **POLLUTION FROM DIFFUSE SOURCES** - including agricultural runoff; urban runoff; runoff from on-site waste disposal systems; runoff from active, reclaimed or abandoned coal and strip mines.
2. **CONTAMINATION OF DRINKING WATER SUPPLIES** including surface and ground waters for both urban and rural uses by diffuse and point sources, and by the disposal of toxic and hazardous wastes on the land.
3. **TOXIC AND HAZARDOUS WASTE DISPOSAL** - including their control, treatment, disposal and impact upon land, water and air resources.
4. **POLLUTION FROM POINT SOURCES** - including municipal and industrial sources not yet in compliance with their NPDES permits.
5. **IMPACTS OF FLOODING AND DRAINAGE** - including flood damages, the use of flood plains and alternative structural and non-structural means of controlling floods and reducing flood damages.
6. **IMPACTS OF WATER RESOURCES DEVELOPMENTS** - including the impacts on various land uses caused by structural and non-structural water resources developments such as the extension of water mains and sewers into rural areas; flood control projects; hydro-electric power generation; water-based recreation; etc.
7. **INSTREAM FLOWS NEEDS** - including interrelationships among water quality, water quantity and land use practices on the instream flow needs for fish, wildlife, and recreation and the optimum development and protection of these instream uses.

8. **IMPACTS OF SYNTHETIC FUEL DEVELOPMENT** - including requirements for water and impacts of the disposal of wastes from these processes into waters and onto the land.
9. **IMPACTS OF ATMOSPHERIC POLLUTION** - including the effects of acid precipitation and atmospheric fallout on water quality and the environment.
10. **ALLOCATION OF WATER RESOURCES** - including the development of contingency plans for the allocation and conservation of limited water supplies among competing water users during periods of low stream flows.

Subsequently, the Directors of the Water Resources Research Institutes in the Great Lakes, Upper Mississippi and Ohio River Basin's met to identify from their State problems the major water resources research priorities for the Region. A listing of these priorities is included at the end of this Section of this Report. The focus of the 1987 Ohio Water Research Institute Program will be directed at some of these crucial needs and at an assessment of the institutional/legal constraints in the development of programs to attempt to control non-point sources of pollution.

The project by L. S. Fan entitled "Optimum Design of Fluidized Bed Bioreactors for Wastewater Treatment" explored the design criteria for an innovative two-stage fluidized bed bioreactor in which the three major processes of cell immobilization, biodegradation and biofilm control were combined in a single unit. This wastewater treatment process is felt to be a substantial evolution in the operational technology of bioreactor design; and the successful completion of this project could result in the development of an innovative, reliable and considerably less costly wastewater treatment system. Dr. Fan held a Section 105 grant from the United States Geological Survey for a related project entitled "A Novel Two-Stage, Three-Phase Fluidized Bed Bioreactor with Immobilized Living Cells for Wastewater Treatment Applications".

Two of the projects explored the fate and transport of agricultural chemicals as they moved through soils toward the groundwater table. The project by Dr. Ruedisili and Mr. Gallagher of the Geology Department at the University of Toledo and Dr. Baker of the Water Quality Laboratory at Heidelberg College studied the effects that subsurface agricultural drains have on the movement of pesticides to groundwaters. The project by Drs. Traina and Logan of the Agronomy Department at The Ohio State University explored the potential impacts that interactions and reactions between herbicides and existing humic materials have on the fate and transport of the herbicides in the groundwater.

Dr. Gordon's project was a cooperative effort involving the Ohio EPA, the Ohio DNR and the Nature Conservancy in examining and assessing the potential institutional and legal constraints that might hinder the development of programs for the management of non-point sources of pollution.

The technology transfer programs of the Water Resources Center continued to disseminate information about the water resources of Ohio to the local and state decision-makers, and provided technical assistance to help resolve some of the state's major water problems.

Training on these research projects was provided to seven graduate students in the disciplines of Chemical Engineering, Hydrogeology, Agronomy, City and Regional Planning, and Environmental Biology. In addition, three undergraduate students from Chemical Engineering and Agronomy gained practical knowledge and training by working on these projects.

REGIONAL RESEARCH PRIORITIES

Great Lakes - Upper Mississippi - Ohio River Region

A. Groundwater contamination

1. Track pollutants through the vadose zone to the groundwater and determine their rate of dissipation in the aquifer.
2. Assess the impacts of the disposal of municipal and industrial wastes and effluents on groundwater systems.
3. Evaluate sources of recharge of the principal aquifers in the region.
4. Determine the effects of the storage of waste heat in aquifers on groundwater quality.

B. Pollution of lakes and streams from non-point sources

1. Assess relative effectiveness of non-point pollution control "best management practices" to meet the demands of P.L. 92-500.
2. Evaluate the effects of atmospheric fallout and precipitation (acids, toxic metals and hazardous trace organics) on public health and the aquatic environment.
3. Estimate the effects of drainage from land use activities in urban areas on surface water quality.
4. Model sediment transport processes and devise techniques for determining sediment delivery ratios.
5. Determine the relative effectiveness of voluntary programs enhanced by various incentives and regulation as mechanisms of implementing non-point pollution control.
6. Predict the impacts that agricultural technologies will have on surface and ground water resources.

C. Adverse water resources impacts of energy production and mining.

1. Evaluate the impacts that drainage from mining activities will have on the incursion of acids, toxic metals, radio nuclides and hazardous organic compounds into the environment.

2. Assess atmospheric and aquatic pollution from coal-fired electric generation plants.
3. Assess legal, economic, environmental and social impacts and develop means for resolving water user conflicts associated with siting, constructing and operating energy conversion facilities and mining operations.
4. Examine the potential benefits, public and environmental, from the reclamation of heated waters from power generation.

D. Potential insufficiency of waters for agriculture and rural communities

1. Determine optimal water requirements for crop production and develop practical methods for irrigation scheduling.
2. Evaluate criteria for establishing minimum requirements for the drainage of imperfectly drained soils of the region.
3. Develop water conservation practices and methods for holding and temporarily storing surface and drainage waters for reuse in periods of seasonal suboptimal precipitation.

E. Loss and degradation of water based fish and wildlife habitat

1. Define the functional and economic value of wetlands including ecological and hydrological mechanisms that influence their integrity.
2. Develop acceptable mechanisms, including incentives and legislation, for preserving publicly and privately owned wetlands.
3. Determine the quality and quantity of instream flow necessary to maintain an active and viable aquatic biota.
4. Determine the potential and incentives needed to increase wildlife and waterfowl production on private lands.

F. Miscellaneous

Develop the relationship between commercial/commodity and recreational use of the major lake and river systems of the region. Research emphasis should be placed on development of sufficient water-based recreational facilities in urban settings.

SYNOPSIS

Project Number: 02

Start: 07/87 (actual)

End : 06/89 (expected)

Title: Optimal Design of Fluidized Bed Bioreactors for Wastewater Treatment

Investigators: Fan, Liang-Shih, The Ohio State University, Columbus

COWRR: 05D **Congressional District:** Fifteenth

Descriptors: fluidized bed process, biological wastewater treatment, phenols, optimal reactor design

Problem and research objectives:

Stringent demands and regulations on drinking water quality and on pollution control of water supplies has created a need for an efficient and economical water treatment system.

One of the most promising new technologies for wastewater treatment is the fluidized bed bioreactor, which is felt to be a substantial evolution in the operational technology of bioreactor design. The three phases of the fluidized bed bioreactor system are: immobilization (biofilm attachment and cultivation), biodegradation, and biofilm control and/or replenishment of fresh solid supports for new biofilm formation.

Exploring and testing the design criteria of an innovative two-stage fluidization bed bioreactor for efficiency and cost effectiveness was the objective of this research.

Problems encountered in earlier designs were the length of time required for biofilm cultivation before start-up, the need for frequent monitoring of particle replenishment and quality control. To offset these problems a two-stage fluidized bed bioreactor was designed which combined the three major processes into a single unit. This bioreactor was designed to eliminate the inefficient steps in the system and to significantly improve the efficiency and economy of wastewater treatment.

The successful completion of this project could result in developing an innovative, reliable and cost effective treatment system.

Methodology

A study was made of the flow properties and behavior of the bioparticles in the first stage of the liquid-solid fluidized bed column. This study included: minimum fluidization velocity, terminal velocity, and bed expansion characteristics.

Solid, spherical particles with densities ranging from 1.05 to 1.32 g/cm³ and diameters ranging from 1.0 to 2.5 cm were used in the study. The properties of the particles simulate those of the bioparticles ordinarily employed in fluidized bed wastewater treatment processes. The minimum fluidization velocity measurement was based on the bed pressure drop-liquid velocity relationship. An inclined manometer was used to detect the pressure drop in the bed since the density difference between the solid particles and water was so small. An electroresistivity probe was used to determine the gas holdup and bubble size distribution in the gas-liquid-solid fluidized beds containing low density particles.

The height of the first and second stages of the bioreactor used in these studies was 60 cm and 120 cm, respectively. The internal diameter of both stages was 7.6 cm.

Principle findings and significance

The two-stage fluidized bed bioreactor was constructed according to the design in the proposal. The automatic particle elutriation process of the bioreactor was tested by using a binary mixture of various sized, solid particles. The results showed that by controlling the rate of liquid flow the particles with smaller terminal velocity were transported smoothly into the second stage.

The flow behavior studies of the simulated bioparticles demonstrated that the correlation equation proposed by Wen and Yu can be used to predict the minimum fluidization velocity for the low density particles to within ten percent. The terminal velocity of the particles was also determined. There was good agreement between the experimental data and the correlation equation proposed by Clift's et al.

The bed expansion behavior of the low density particles was found to follow the Richardson-Zaki equation for void ratios in the intermediate (0.5 to 0.8) range. However, when the terminal velocity of these particles was determined by extrapolating the Richardson-Zaki equation to a void ratio of 1.0, the value deviated from the terminal velocity determined by the falling drop method.

The gas holdup decreased when the solid terminal velocity was increased. The average bubble chord length increased when the terminal velocity of the solid particles was increased. Oxygen transfer results showed the solid particles used for biofilm attachment should be as small as possible, but bioparticles with small terminal velocities will

encounter elutriation problems. The optimum size and density of bioparticles was found to be 0.5 mm and 1.05 g/cm³ for the present reactor design. In order to have optimum biodegradation, optimum sized bioparticles need to be used.

The density of biofilms in a liquid-solid fluidized bed was found to be lower than that of biofilms obtained from the draft-tube gas-liquid- solid fluidized bed bioreactor. Although higher biofilm density signifies higher biomass holdup, higher diffusional resistance for substrates and oxygen was found.

A comprehensive mathematical model has been formulated to simulate the complex relationship among the biodegradation efficiency, the biofilm density, the diffusional resistance inside the biofilm, and external (substrates and oxygen) mass transfers. This mathematical model successfully predicted the experimental data of phenol biodegradation in the fluidized bed bioreactor. The model can be used to identify the optimal operating conditions for each stage of the two-stage bioreactor.

Publications and Professional Presentations:

- (1) Fan, L-S, K. Fujie, T-R Long, and W-T Tang, "Characteristics of a Draft Tube Gas-Liquid-Solid Fluidized Bed Bioreactor with Immobilized Living Cells for Phenol Degradation," *Biotechnol Bioeng.*, 30, 498-504 (1987).
- (2) Wisecarver, K. D., and L-S Fan, "Biological Phenol Degradation in a Gas-Liquid-Solid Fluidized Bed Reactor," paper presented at AIChE Annual Meeting, Nov. 15-20, New York (1987); *Biotechnol. Bioeng.*, (In press).
- (3) Tong, C. C., and L-S Fan, "Concentration Multiplicity in a Draft Tube Fluidized Bed Bioreactor Involving Two Limiting Substrates," *Biotechnol. Bioeng.*, 31, 24-34 (1988).

Training

(a) M. S. Theses

None

(b) Ph. D. Dissertations

Wisecarver, K. D., "Characterization and Modeling of Gas-Liquid- Solid Fluidized Bed Reactors, " (1987).

SYNOPSIS

Project Number: 03

Start: 07/87 (actual)

End : 06/89 (expected)

Title: Application of Gaming and Decision Analysis to the Assessment of Legal/Institutional Arrangements for Nonpoint Pollution Control

Investigator: Gordon, Steven I., The Ohio State University, Columbus

COWRR: 06E **Congressional District:** Fifteenth

Descriptors: Decision making, gaming analysis, non-point pollution control, institutional constraints

Problem and research objectives:

Watersheds face significant problems from nonpoint source water pollution when they are dominated by agricultural and urban land use. Regulatory agencies have inadequately addressed this problem in terms of possible standards and controls, monitoring activities, and enforcement mechanisms.

The fragmentation of responsibility among local, regional, state and federal organizations contributes to the problem. When agencies lack clear authority to control the pollution by establishing regulations, conducting monitoring activities and/or enforcing existing regulations, they often ignore the problem or consign it a secondary priority. Rather than take the steps necessary to solve the problem at the risk of a potential political controversy, they often choose to do nothing. By default this inaction results in water quality degradation.

The primary research objective is to assess the impacts of agency personnel and government officials on the administration of nonpoint pollution abatement programs. A case study in the Big Darby Creek Basin in Ohio was used to help define the nature of these institutional, legal and management problems.

A secondary objective is to use the results to educate local, state, and federal officials about the nature of these administrative and legal problems and to suggest possible mechanisms to help reduce nonpoint pollution problems.

Methodology:

A general questionnaire was first used to determine the types of agricultural nonpoint pollution control programs that are currently used in the study area. The questionnaire was given to a sample of eighteen federal, state and local agency personnel that work with nonpoint pollution programs in the five-county, Big Darby Creek Basin.

A physical model of the projected nonpoint water pollution impacts of different management/land use combinations was assembled using the resources of a related project. The Agricultural Nonpoint Source Pollution Model (AGNPS) was used to project the potential impacts of various land use and management scenarios. These data were incorporated in some of the later analyses.

A second questionnaire which utilized decision analysis techniques to isolate responses to a variety of legal/institutional arrangements for nonpoint pollution control programs was then distributed. Respondents were asked to allocate new monies among three hypothetical farm programs: one in business management, one in nonpoint pollution, and one in farm production improvement.

In order to assess the impact of a changing political climate on the administrators, variations in the instructions were worded to reflect a neutral, a pro-management program, and a pro-nonpoint pollution program stance by state and local officials. General questions concerning the respondents attitudes toward environmental problems in general and a set of questions aimed at defining their general feelings concerning control measures were included in the questionnaire.

Finally a computer game called, "*Manage the Big Darby*" was designed. The game will be used as both a research and an educational tool. It will be used to gauge responses to the problems of managing nonpoint source pollution and to educate participants to the nature and extent of the problem and its potential solution.

Principal findings and significance:

This research has shown that the division of authority and power produces an ineffectual program for the control of agricultural nonpoint source pollution.

Although the respondents in the sample agreed that nonpoint pollution was a major environmental problem for this area, only five percent of the farmers in the area participate in programs to reduce this source of pollution.

When deciding which programs to give money to, a significant proportion of the agency personnel chose to conform to local political opinion, regardless of their own beliefs on environmental issues. A significant number of the respondents changed their allocations to and from the nonpoint pollution program to match the bias of the state and local officials that had been provided with the questionnaire. This finding is of particular significance, when attempting to structure new nonpoint pollution programs.

The current structure of related programs has agency personnel dividing their time between concerns over pollution and other farm management tasks. If they react so strongly to political incentives, this implies that the pollution control programs will receive much less of their attention unless the programs are explicitly structured to force a particular commitment.

These results are being embedded in the first version of the computer game and will be used to gain further insight into administrative behavior regarding nonpoint pollution programs.

Publications and professional presentations:

1. Steven I. Gordon and John Simpson, "Nonpoint Pollution Problems in the Big Darby Creek Basin". Presentation to the Board of Directors, Ohio Chapter, The Nature Conservancy, March, 1988.
2. John Simpson and Steven I. Gordon, "The Integration of a Low Cost Digital GIS with a Nonpoint Source Water Pollution Model to Evaluate Alternative Land Management Strategies," Ohio Academy of Science Annual Conference, April 30, 1988.

M. S. Theses - None

Ph. D. Dissertations - None

SYNOPSIS

Project Number: 04

Start: 05/87 (actual)

End: 06/88 (actual)

Title: A Study of Potential Groundwater Contamination from Selected Agricultural Pesticides

Investigators: Ruedisili, L. C., The University of Toledo, Toledo
Baker, D. B., Heidelberg College, Tiffin
Gallagher, R. E., The University of Toledo, Toledo

COWRR: 5B Congressional District: University of Toledo - 9th
Heidelberg College - 5th

Descriptors: Ground-water pollution, pesticides, herbicides, leaching, tile drainage, water analysis, aeration zone

Problem and research objectives:

Research concerning nonpoint source pollution by pesticides has traditionally focused on soil erosion and the contribution of sediment and agrichemicals to surface waters. Relatively little research has been done to evaluate the relationship of pesticides in tile effluent and ground water.

The objectives of this research were to: (1) compare the rates of transport of herbicides in two soils, (2) study the effect that subsurface drainage systems have on the movement of pesticides to deeper ground water, and (3) evaluate the leaching process of agricultural pesticides as potential sources of ground water contamination in hydrologic regimes similar to those in northwest Ohio.

The herbicides that were studied are those that are commonly used to control weeds in corn and soybeans in northwest Ohio and similar agricultural areas. The herbicides being examined include: alachlor (LASSO), atrazine (AATREX), cyanazine (BLADDEX), metolachlor (DUAL), metribuzin (SENCOR), and simazine (PRINCEP).

Methodology:

This study was done on two 17 acre fields. One field had a silty-clay soil and no-till crops while the other site had a sandy-loam soil with a low to moderate organic matter content (1 - 2.3 wt. percent) and conventional tillage practices were used. Both fields had isolated subsurface drainage systems, a shallow depth to the water table, and little topographic relief. They also were generally under recharge conditions, had a laterally homogeneous soil profile and had similar meteorological conditions. A history of farming activities and pesticide applications since 1982 was obtained for each of these fields.

In each field, ten, 2-inch-diameter PVC monitoring wells with 12-inch screens were installed at depths of 5.5, 7, and 10-12 feet. For each pair of wells screened at the same depth, one was located next to a tile drain and the other midway between the tiles. Wells with 36 inch screens were installed around the perimeter of the fields to establish the local hydraulic gradient and ambient pesticide concentrations in the ground water.

Water sample collection focused on those periods with effluent discharging from the drain tiles and at the time the greatest concentrations of pesticides were likely to be present. Prior experience indicated that these times are in the spring, early summer, and late fall. Tile effluent and groundwater sampling was done at least once a week, especially following precipitation events, and during the critical period immediately following pesticide application in 1987.

Water samples from the monitoring wells and tile effluent were collected in one quart, wide-mouth Mason jars with Teflon-lined lids and were refrigerated until analyzed. During sampling, in order to prevent cross-contamination between samples, jars were individually filled using a piece of Tygon tubing inserted into the well and a pressure/vacuum hand pump. All monitoring wells were completely evacuated at least once prior to sample collection. Grab samples of the tile effluent were collected from the drainage outlets during each sampling episode if there was flow.

Soil sampling was done in the spring and fall of 1987 to provide information on pesticide migration in the unsaturated zone. In each field soil cores were taken in one-foot increments to a depth of 3 feet and composited according to depth. The physical properties and organic matter content of the soils was analyzed in laboratories at the University of Toledo.

All analysis of soil and water samples for pesticide contents were performed by the Water Quality Laboratory at Heidelberg College. A dual capillary column gas chromatography was used in the broad spectrum analysis of soil and water samples for pesticide concentrations.

Principal findings and significance:

Only the 1987 water quality data from the shallow wells and tiles has been retrieved from the computer and fully calibrated. Preliminary data from both fields indicates the presence of alachlor, atrazine, cyanazine, and simazine.

Significant temporal variability was observed in the samples of both tile effluent and ground water. Atrazine generally exhibits the highest concentrations of the herbicides, particularly for the two months immediately following pesticide application. Atrazine and simazine tended to be transported more quickly and in higher concentrations to the tile drains in the sandier soil.

Pesticide concentrations in the tile effluent were generally less variable and tended to reach maximum concentrations earlier than in ground water. Peak herbicide concentrations in the tile drainage appeared to be a precursor of peak values in ground water. However, concentrations in the tile effluent did not seem to quantitatively represent what was found in deeper ground water.

In comparing the two soil types, the data suggests the tiles were more effective in intercepting herbicides leaching below the root zone in the sandier soil. Here the subsurface drains seem to “protect” deeper ground water by collecting the leaching pesticides and discharging them to the surface where the chemicals are more susceptible to degradation and transformation processes. Tiles in the silty-clay soil appear to have less influence on the downward movement of pesticides and in the case of atrazine, may actually be contributing to ground water concentrations.

This research project was severely impacted by drought conditions that existed at both fields throughout the 1988 growing season. Total precipitation for the year was about nine inches below average. It is uncertain how data from this growing season would compare with pesticide behavior under more normal conditions.

Publications and professional presentations:

- (1) Ruedisili, L. C., 1988, "Pesticides in Tile Drainage and Shallow Groundwater in Ottawa and Lucas Counties", (Abs.), in **Pesticide Exposure Assessment in Surface Waters**, Heidelberg College, Tiffin, Ohio, April, p. 51
- (2) Ruedisili, L. C., "Pesticides in Tile Drainage and Shallow Groundwater in Ottawa and Lucas Counties, Ohio", presented at the Pesticide Exposure Assessment in Surface Waters Conference, Oct. 28-29, 1987, Heidelberg College Water Quality Lab, Tiffin, Ohio.

M. S. thesis:

Keim, A. M., "A Field Study of Selected Agricultural Herbicides in Shallow Ground Water and Tile Drainage in Lucas and Ottawa Counties, Northwest Ohio", The University of Toledo, in press.

SYNOPSIS

Project Number: 05

Start: 07/87 (actual)

End : 06/89 (expected)

Title: Effect of Complexation by Soluble Humic Substances on the Aqueous Transport and Chemistry of Pesticides

Investigators: Traina, Samuel J. and Terry J. Logan, The Ohio State University, Columbus

COWRR: 05B **Congressional District:** Fifteenth

Descriptors: Groundwater quality, organic compounds, physical chemistry, soil chemistry, trace organics, water chemistry

Problem and research objectives:

Most transport models for pesticides have been restricted to model systems with solution compositions far removed from those typically found in surface and soil waters. There is reason to believe that the results of these studies may not coincide with the chemical and physical behavior of humic substance-pesticide complexes formed under more natural conditions. In particular the assumption - that the chemical properties of "free" (uncomplexed) pesticide molecules are the most pertinent factors which control pesticide movement - may be erroneous.

It is known that many pesticides form strong aqueous complexes with dissolved humic substances (HS). Such complexes can comprise a significant fraction of the total pesticide present in aquatic systems.

This research studied the formation of humic substance-pesticide complexes. Variations in the ionic composition of the aqueous environment effect the colloidal structures of NDOC (non-dissolving organic compounds) polymers in aqueous solution. This in turn should have a profound effect on complex formation.

This research included the effects of cation type, pH and ionic strength on the binding of naphthalene and anthracene by water soluble soil organic matter (WSOC) and soil, and the subsequent effects on adsorption by soil. Two polyaromatic hydrocarbons, naphthalene and anthracene, were used for this research because they share many of the chemical properties with a number of pesticides.

The knowledge gained from this research is critical to the understanding and prediction of the properties governing the toxicity, chemical behavior, and transport of pesticides in natural environments. Complexation of organic solutes by HS has been shown to enhance the water solubilities of compounds which do not normally dissolve well in water, to reduce their biotoxicities, to change their rates of bioaccumulation, and to decrease their adsorption to soil and sediment surfaces.

Methodology:

Preparation of water soluble organic carbon (WSOC) and humic acid (HA):

Samples of Carlisle muck (euic, mesic typic medisaprist, northwest Ohio) were Na-saturated in the laboratory by washing with 1 mol kg^{-1} NaCl. The Na-saturated soil was then dispersed by repeated rinsing with deionized water. From this process a dark brown to black colored solution was produced. The solution was then centrifuged, decanted, and filtered with 0.2 micron, polycarbonate membrane filters to separate it from the solid phase. This sample was then dialyzed with water until a negative silver test for chlorine was obtained. In order to reduce the polyvalent cation content, the "salt-free" solution was again dialyzed with Na-saturated Chelex 100. The resulting "Na-saturated", "salt-free" aqueous organic matter solution (stock WSOC) was then stored in glass at 277 K.

The total carbon content of the stock WCOS solution was determined with a Dohrmann Xertex, DC 80 dissolved carbon analyzer.

The Carlisle humic acid was extracted from Carlisle soil with the standard method sanctioned by the International Humic Substance Society.

Effects of cations, pH and ionic strength:

Aqueous solutions of PAH (either naphthalene or anthracene) were titrated discontinuously with either WSOC or HA, in the presence of either NaClO_4 , $\text{Ca}(\text{ClO}_4)_2$, or $\text{Al}(\text{ClO}_4)_3$.

Separate experiments were carried out over a pH range of 2 to 7, and an ionic strength range of 0.05 to 0.5 mol L^{-1} .

Reaction of HS with naphthalene and anthracene resulted in the quenching of the intrinsic fluorescence of the PAH molecules. The quenching was caused by the formation of a ground-state PAH-HS complex.

Principle findings and significance:

Decreases in the intrinsic fluorescence of naphthalene and anthracene resulting from additions of HS were used to calculate conditional PAH-HS stability constants ($^{\circ}K_{oc}$) for each of the electrolyte systems investigated.

In all cases, increased aqueous concentrations of HS caused an increase in the formation of PAH-HS complexes.

Changes in pH value from 1.5 to 7.3 (in the presence of $0.05 \text{ mol L}^{-1} \text{ NaClO}_4$) and changes in ionic strength from 0.05 to 0.5 mol L^{-1} (in the presence of either $\text{Ca}(\text{ClO}_4)_2$ or $\text{Al}(\text{ClO}_4)_3$) had no effect on the binding of naphthalene by WSOC.

In homoionic systems of either NaClO_4 , $\text{Ca}(\text{ClO}_4)_2$ or $\text{Al}(\text{ClO}_4)_3$ (ionic strength = 0.05 mol L^{-1}), the formation of naphthalene-WSOC complexes decreased in the order $\text{Na} > \text{Ca} > \text{Al}$, and naphthalene-HS complexes decreased in the order of $\text{Na} > \text{Ca} > \text{Al}$. For anthracene-WSOC systems, complex formation decreased in the order $\text{Na} > \text{Ca} = \text{Al}$.

Increases in cation valence appear to increase the flocculation of WSOC and HA, presumably through a decrease in the ionization of acidic functional groups. This reduces the molar volume of the "hydrophobic" regions of the HS polymers and decreases binding of the PAH solutes.

The second year's efforts on this project will include: 1) an extension of these experiments to reference humic substances and to other nonpolar organic solutes, 2) further elucidation of the nature of the PAH-HS complexes with dynamic light scattering and NMR spectroscopy, and 3) the effect of cation type on the adsorption of PAH-HS complexes to reference clays.

Publications and professional presentations:

1. Traina, S. J., D. A. Spontak, and T. J. Logan (in press) Effects of cations on complexation of naphthalene by water soluble organic carbon, J. Environ. Qual.
2. Traina, S. J., D. A. Spontak, and E. O'Loughlin. Effects of cations on the complexation of pesticides by water soluble organic carbon. Soil Science Society of America, Dec. 2, 1987, Atlanta, Georgia.
3. Traina, S.J. Effects of cations on the complexation of polycyclic aromatic hydrocarbons by humic and fulvic acids. Gordon Research Conference. Environmental Science: Water. June 18-14, 1988, New Hampton, New Hampshire.

INFORMATION TRANSFER ACTIVITIES

A series of tasks were continued or initiated to transfer and disseminate information developed by researchers affiliated with the Water Resources Center to a wide range of State, Federal, County and Municipal agencies; to the private sector; to the academic community and to private citizens throughout Ohio.

Water Resources Center Library

The Water Resources Center has maintained a library of water resources related publications since its establishment in 1965. For several years the Center for Lake Erie Area Research (CLEAR) and the Water Resources Center jointly maintained a library. This year CLEAR's office moved to another campus area and the libraries again became independent entities. This year the Water Resources Center resumed full support for the operation of the library.

Water Luncheon Seminars

The Water Resources Center continued to co-sponsor a bi-monthly Water Luncheon Seminar Program for the water resources community in Central Ohio. This program, was developed cooperatively with The Ohio Department of Natural Resources (ODNR), the Ohio Environmental Protection Agency (OEPA), the Soil Conservation Service (SCS), the District Office of the United States Geological Survey (USGS), and the Agricultural Engineering Cooperative Extension Service of The Ohio State University. More than seventy water resources professionals from Federal, State, County and Municipal Agencies, the private sector and the academic community attend this forum to discuss current state, federal and local water policy issues, problems, programs and research results.

This year the Water Resources Center provided speakers for two meetings and jointly sponsored two other seminars. The December Water Luncheon Seminar was a special meeting held in conjunction with the Third International Workshop on Land Drainage. More than 140 people representing 18 countries attended this seminar. The March Water Luncheon Seminar was jointly sponsored with the Ohio Biological Survey, the Ohio Department of Natural Resources and the Water Resources Center, as an update on the Ohio River following the oil spills in January.

In addition to providing speakers for the luncheon seminars, the Center provides the administrative and financial support for producing and mailing the announcements and organizing the seminars and provides technical equipment to assist the speakers with their presentations.

Water Luncheon Seminar, FY 1987

Date	Speaker/(Sponsoring Agency)	Topic
9/15/87	Dr. Henry Smith, Director International Center for Water Resources Management Central State University (Water Resources Center)	The Program and Goals for the International Center for Water Resources Management
11/10/87	Joe Harrington State Conservation Engineer (Soil Conservation Service)	Computer Program for Visual Resource Design
12/8/87	Dr. Marvin E. Jensen, Director Colorado Institute for Irrigation Management Colorado State University (The OSU Cooperative Extension Service and the Water Resources Center)	World Irrigation Trends and Drainage Impacts
1/12/88	Chuck Taylor Chief, Division of Solid and Hazardous Waste Management (Ohio Environmental Protection Agency)	Pending Solid Waste Legislation - An Update
3/8/88	Dr. William Mitsch Professor, School of Natural Resources Executive Director, Ohio River Basin Consortium for Research and Education (Ohio Biological Survey, Ohio Department of Natural Resources & the Water Resources Center)	Ohio River Ecosystem: Conserving, Educating and Spilling Oil
5/10/88	Dr. Richard L. Shank Director Ohio EPA (Water Resources Center)	Water Programs Update from the Ohio EPA

Information Dissemination Activities

The Center continued to meet with the leading water resources officials in the state to share information on current water management and policy issues; to seek continued support for the water research program and disseminate the information and technology developed through this program and others at the universities throughout the state and region.

In response to a suggestion from the Water Resources Center's evaluation team a quarterly newsletter is being developed. The editor will be Mrs. Carol Moody. She is the secretary to the Center and she has journalism experience. Production and distribution are planned to begin in FY 1988.

Consultation and Collaboration Activities

The Center's Director has continued to meet with the leading water resources officials in the state for the purposes of consultation and collaboration to identify the major water problems and the research needs of the state and region; to share information on current water management and policy issues; to seek continued support for our water research program and to disseminate the information and technology developed through this program and others at the universities throughout the State and Region.

The Director was recently appointed by the Governor of Ohio to serve on the Ohio Water Advisory Council, a statutory commission that advises the Water Division of the Ohio Department of Natural Resources.

This year the Director was appointed by the Mayor of the City of Columbus to serve on the Solid Waste Recycling Task Force. He is a member of the Technical Advisory Committee.

The Director serves on the Board of Directors to the Ohio River Basin Research and Education Consortium. And he has assisted in developing the organization of the newly created International Center for Water Resources Management at Central State University, a historically black university.

The Director is the Lead Delegate to the Universities Council on Water Resources (UCOWR) and is a past member of the Board of Directors; he serves on the Water Programs Public Advisory Group to the Ohio Environmental Protection Agency and is a member of the Toxics Technical Advisory Committee; and he is a member of the Ohio Inter-Agency Water - Use Data Coordinating Committee for the Ohio District of the U. S. Geological Survey.

COOPERATIVE ARRANGEMENTS

Program Development

A call for pre-proposals for the Fiscal Year 1987 State Water Resources Research Program was sent to research administrators and qualified faculty investigators at over 40 private and public colleges and universities throughout Ohio on November 15, 1986. This announcement, contained the research priorities identified for the major water problems in the Great Lakes, Upper Mississippi and Ohio River Basins by the Water Resources Research Institutes in the Region.

The announcement also required interested researchers to request a copy of the Preliminary Proposal Application Form which was to be completed and returned to the Water Resources Center in mid-January, 1987. More than 250 names were included on the distribution list. In addition to this general mailing, a separate letter was sent to the President of Central State University, encouraging him to have the faculty participate in the Program.

Pre-Proposals/Federal Guidelines

Preliminary Proposal Application Forms were requested by and sent to thirty-one investigators and research administrators at twelve colleges and universities in Ohio. A copy of this Application Form was also requested by Teater and Associates for Central State University. Teater and Associates are the program development consultants for the recently established International Center for Water Resources Management at Central State University. However, no Historically Black University responded. A copy of the federal guidelines for the Program were enclosed with the Form.

Evaluation/Selection Procedures

Twenty pre-proposals from eight universities and colleges throughout the state were submitted for evaluation and consideration. These pre-proposals were subjected to a review by all of the members of the Water Resources Center's Advisory Committee. In addition, the twenty pre-proposals were distributed to the various divisions within the three principal state and federal water-related agencies in the State by the representatives of these agencies who serve on the Advisory Committee, requesting that the divisions review the proposals. The three agencies included in this evaluation were the Ohio Department of Natural Resources, the Ohio Environmental Protection Agency, and the District Office of the United States Geological Survey.

The results of these reviews were presented at a meeting of the Advisory Committee where this panel selected ten of the pre-proposals and instructed the Center's Director to request fully developed proposals from the investigators for the Committee's further consideration.

Only nine of the selected pre-proposals were developed more fully and were re-submitted for consideration. The proposals were subjected to a technical review by at least three qualified evaluators selected by individual members of the Water Resources Center's Advisory Committee. Many of these evaluators were from state and federal agencies and from universities other than The Ohio State University.

The results of these reviews were presented at a meeting of the Advisory Committee and this panel ranked the leading six proposals in the order they felt would best meet the needs and objectives of the Water Resources Center's program. The Advisory Committee then instructed the Center's Director to incorporate as many of these projects as Federal funds would permit into the FY 1987 Program, and to develop a project for information transfer for the Center. There was only enough Federal monies to support four projects.

The membership of the Water Resources Center's Advisory Committee, which includes representatives from five colleges and eleven departments of The Ohio State University and the three representatives of the principal water-related state and federal agencies is included in this report.

Regional Cooperative Initiatives

The four projects selected for this program were compared with the FY 1987 Program synopses of the projects included in the programs of the other Water Resources Institutes in the Great Lakes, Upper Mississippi and Ohio River Basin to ensure that there was no duplication of efforts in the Region's research programs.

The Ohio State University has agreed to continue as a Charter Member of the Ohio River Basin Research and Education Consortium, and the Director of the Water Resources Center will continue to serve as one of the University's three representatives to the Consortium.

The Director has also been nominated to serve as The Ohio State University's liaison with the Center for International Water Resources Management at Central State University.

Program Management

At least once each quarter, the Director contacts the Principal Investigator on each research and information transfer project to discuss progress made during the quarter and to discuss the next quarter's plan of activities. At this same meeting budget details are reviewed and discussed, and necessary operating and reporting procedures to the Water Resources Center and to The Ohio State University Research Foundation's business office are described.

Progress Reports or Completion Reports will be prepared for each Project by the Principal Investigators and will be used by the Program Director to prepare the Program Final Report.

All of the investigators are urged to publish the results of their findings in the technical literature of their major disciplines and in other journals that are appropriate to the topic of their research. They are also encouraged and invited to present their findings at the Water Luncheon Seminar that is a part of the technology transfer activities of the Center.

The manuscripts that constitute the project completion reports are first reviewed by the Director of the Water Resources Center. As needed, the Director seeks the advice and council of appropriate state, federal and university scientists for methods of enhancing the value of the technical completion reports to the water-related community in the state and in the region.

WATER RESOURCES CENTER ADVISORY COMMITTEE

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3. Dr. Robert C. Stiefel
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16. Dr. John F. Estenik

OHIO DEPARTMENT OF NATURAL RESOURCES

17. Dr. William Mattox

UNITED STATES GEOLOGICAL SURVEY

18. Mr. Steven Hindall
District Chief

TRAINING ACCOMPLISHMENTS

The following tabulation shows, by fields of study and training levels indicated, the numbers of individuals participating in projects that were financed in part with this grant.

Training Category	Training Level				Total
	Undergraduate*	Master's Degree	Ph.D. Degree	Post - Ph.D.*	
Engineering					
—Chemical	1	2			3
Biological/ Natural Science					
—Biology			1		1
Geology					
—Hydrogeology		1			1
Agronomy	2	1			3
City & Regional Plan		1	1		2
<hr/>					
TOTALS	3	5	2		10